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COORDINATES OF FEATURES ON THE GALILEAN SATELLITES.(U)
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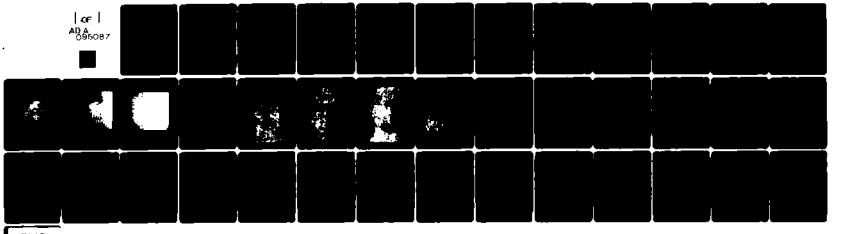

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COORDINATES OF FEATURES ON THE GALILEAN SATELLITES

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June 1980

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James A. Roth, Thomas A. Hauge, and David Douglass of Rand were responsible for the selection, identification, and measurements of the control points on the individual pictures. We are appreciative of their dedication and care in carrying out this important part of the work.

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I. INTRODUCTION

One product of the current exploration of the solar system is the publication of maps of those bodies with solid surfaces. These maps show the relative positions of topographic features, one-to-another, and are used as bases for correlating a variety of measurements and pictorial data and for regional geologic mapping. In order to produce a map of a planetary surface, it is necessary to first establish a coordinate system for the body and then to determine the latitudes and longitudes of topographic features in this coordinate system. It is the purpose of this paper to define the coordinate systems of each of the Galilean satellites and to present coordinates of features seen in the Voyager pictures of these satellites. The two Voyager encounters with Jupiter are described in Smith et al. (1979a,b). A preliminary report on the progress of the control nets of the Galilean satellites was published by Davies et al. (1979).

The method for computing the control net of these satellites is essentially the same as that used at Mars (Davies, 1972; Davies and Arthur, 1973) and at Mercury (Davies and Batson, 1975) and will not be reviewed here.

Each spacecraft carried two cameras, one with a wide-angle lens and one with a narrow-angle lens. They can be shuttered independently or simultaneously. Pictures were taken of the Pleiades and other star clusters for calibration--using the known coordinates of the stars seen in the pictures, the camera orientation matrices, C, can be determined as well as the focal distances of the camera lenses. The focal distances of the Voyager 1 cameras are 200.293 mm and 1500.19 mm, and those of the Voyager 2 cameras are 200.770 mm and 1503.49 mm (Davies et al., 1979). The matrix relating the orientation of the wide-angle camera to that of the narrow-angle camera can be computed from frames taken simultaneously by each camera. This matrix, $C_{NA}C_{WA}^{-1}$, is given in Table 1 (Davies et al., 1979).

Table 1

THE MATRIX $C_N C_{WA}^{-1}$ RELATING THE CAMERA AIMING AND ROTATION DIRECTIONS OF THE TWO CAMERAS ON EACH SPACECRAFT

$C_N C_{WA}^{-1}$

Voyager 1

$$\begin{bmatrix} 0.9999950588 & -0.0031011413 & 0.0005151430 \\ 0.0031009104 & 0.9999950916 & 0.0004483927 \\ -0.0005165310 & -0.0004467931 & 0.9999997668 \end{bmatrix}$$

Voyager 2

$$\begin{bmatrix} 0.9999966464 & -0.0025304697 & -0.0005512367 \\ 0.0025303754 & 0.9999967838 & -0.0001717796 \\ 0.0005516696 & 0.0001703842 & 0.9999998333 \end{bmatrix}$$

II. THE SATELLITE COORDINATE SYSTEMS

The International Astronomical Union has defined coordinate systems for many of the planets and satellites of the solar system (*IAU Transactions*, 1979). The coordinate systems of synchronous satellites, like the Galilean satellites, are based on a resolution adopted in 1973 (*IAU Transactions*, 1974). These IAU-recommended coordinates were the starting point for the Voyager coordinate systems of the satellites.

The *IAU Transactions*, 1979, contain expressions for the direction of the north poles and the position of the prime meridians of the four satellites. These expressions are given in standard Earth equatorial coordinates of 1950.0 and, except for the rotation term in the positions of the prime meridians, vary slowly with time. Because the two Voyager spacecraft encounters with Jupiter were separated by only four months, the directions of the north poles were computed at a single time and assumed constant for both encounters (Davies et al., 1979). The angle W is measured along the satellite's equator in an easterly direction with respect to the satellite's north pole from the ascending node of the satellite's equator on the standard Earth equator (1950.0) to the point where the prime meridian crosses the satellite's equator. This led to the following values:

Io	$\alpha_o = 268.^\circ01$ $\delta_o = 64.^\circ54$ $W = 262.^\circ7 + 203.^\circ4889538d$
Europa	$\alpha_o = 269.^\circ07$ $\delta_o = 64.^\circ34$ $W = 156.^\circ9 + 101.^\circ3747235d$
Ganymede	$\alpha_o = 268.^\circ45$ $\delta_o = 64.^\circ62$ $W = 195.^\circ8 + 50.^\circ3176081d$
Callisto	$\alpha_o = 268.^\circ25$ $\delta_o = 64.^\circ62$ $W = 158.^\circ0 + 21.^\circ5710715d$

where d = JED-2433282.5.

A point, P, on the surface of a satellite has cartographic coordinates latitude ϕ, west longitude λ, and radius R, and rectangular coordinates X, Y, Z, where $X = R \cos \phi \cos (360° - \lambda)$, $Y = R \cos \phi \sin (360° - \lambda)$, and $Z = R \sin \phi$. Because the X, Y, Z coordinate system is right-handed, $360° - \lambda$ is used in the expressions for X and Y. The Z axis is the axis of rotation of the satellite with north positive. The X axis lies in the plane of the equator, positive in the direction of 0° longitude. The Y axis lies in the plane of the equator, positive in the direction of 270° west longitude. The standard equatorial coordinates of 1950.0 of the point P_x, P_y, P_z can be expressed as

$$\begin{bmatrix} P_x \\ P_y \\ P_z \end{bmatrix} = MV \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

where

$$M = \begin{bmatrix} \cos(\alpha_o+90°) & -\sin(\alpha_o+90°)\cos(90°-\delta_o) & \sin(\alpha_o+90°)\sin(90°-\delta_o) \\ \sin(\alpha_o+90°) & \cos(\alpha_o+90°)\cos(90°-\delta_o) & \cos(\alpha_o+90°)\sin(90°-\delta_o) \\ 0 & \sin(90°-\delta_o) & \cos(90°-\delta_o) \end{bmatrix}$$

and

$$V = \begin{bmatrix} \cos W & -\sin W & 0 \\ \sin W & \cos W & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

If a picture containing P is taken by the spacecraft at S_x, S_y, S_z, the coordinates X_c, Y_c of P on the picture are given by

$$X_c = \frac{\xi}{\zeta} f, \quad Y_c = \frac{\eta}{\zeta} f,$$

where

$$\begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = C \begin{bmatrix} P_x \\ P_y \\ P_z \end{bmatrix} - C \begin{bmatrix} S_x \\ S_y \\ S_z \end{bmatrix},$$

and f is the calibrated principal distance (focal length) and C is the transformation matrix from standard coordinates of 1950.0 into the camera coordinate system. X_c, Y_c, f are expressed in millimeters and R, P_x, P_y, P_z, S_x, S_y, S_z are in kilometers.

Coordinates of the point P are measured on the picture by counting pixels (picture elements) and then removing the vidicon distortions and scaling the pixel coordinates to millimeter coordinates X_o, Y_o at the faceplate of the vidicon. The reseau is used in this transformation. The pixel measurements on the pictures are estimated to the one-tenth pixel and in general are repeatable to a few tenths of a pixel.

Standard photogrammetric methods are used to solve for the unknowns (see, for example, Davies and Arthur, 1973). Approximate values of all parameters are required to initiate the analytical triangulation. The triangulation is a problem in least squares designed to minimize the sum of the squares of the residuals, i.e., $(X_o - X_c)$, $(Y_o - Y_c)$. Observation equations are expressed in terms of those parameters whose values are permitted to vary; the normal equations are formed and solved to give improved values to the desired parameters. In practice, the spacecraft positions S_x, S_y, S_z are never permitted to vary, and the angles of the C matrix are usually variable, as are the latitude ϕ and longitude λ of the control points. The radius at the control points can be fixed, a single mean radius determined for all points, or the radius at each point determined independently.

The control nets of the satellites are computed by means of single-block analytical triangulations. The normal equations are solved by the conjugate gradient iterative method, which is convenient and converges rapidly as the initial estimates of the parameters

are very good. A summary of the control net computations is given in Table 2.

Table 2

SUMMARY OF CONTROL NET COMPUTATIONS OF THE GALILEAN SATELLITES

Parameter	Io	Europa	Ganymede	Callisto
Points	355	106	865	375
Pictures	210	103	137	161
Observation equations	6230	2086	6392	4358
Normal equations	1340	521	2141	1233
Overdetermination factors	4.65	4.00	2.99	3.53
Standard error of measurement, mm	0.02148	0.01497	0.03769	0.02197
Mean radius, km	1816±5	1569±10	2631±10	2400±10

The spacecraft trajectories used in the analytical triangulations result from a study by the JPL Voyager Orbit Determination Group, headed by James K Campbell. This study used pictures taken and reduced by the Optical Navigation Group to update simultaneously the two Voyager trajectories and the ephemerides of the four Galilean satellites. The spacecraft positions relative to the centers of mass of the satellites (S_x, S_y, S_z) are required for the analytical triangulations.

During the picture-taking sequences it was possible occasionally to take simultaneous pictures with the wide-angle and narrow-angle cameras in which two satellites were in the wide-angle frame and one of them with useful surface detail was in the narrow-angle frame. Knowing the locations of the satellites, the wide-angle camera orientation matrix C_{WA} could be determined, and since the matrix $C_{NA}C_{WA}^{-1}$ was known from the star calibrations, the narrow-angle camera orientation matrix could be calculated: $C_{NA} = C_{NA}C_{WA}^{-1}C_{WA}$. Thus, in the control net computations, the camera orientation matrices of a few frames are constrained by weights. Those frames with C matrices computed from simultaneous exposures are given in Table 3.

Table 3

NARROW-ANGLE FRAMES WITH ORIENTATION MATRICES CONSTRAINED BY SIMULTANEOUSLY EXPOSED WIDE-ANGLE FRAMES

Satellite	FDS Frame	Picture Number	2-Pixel Surface Resolution (km)
Io	16322.14	1369J1-003	53.0
	16322.18	1373J1-003	53.0
	16322.22	1377J1-003	53.0
Europa	16323.14	1429J1-003	45.3
	16323.18	1433J1-003	45.2
	16357.07	1663J1-002	39.1
	16357.11	1667J1-002	39.1
Ganymede	16289.32	1207J1-004	66.0
	16289.36	1211J1-004	65.9
	16289.40	1215J1-004	65.9
	16356.55	1651J1-002	47.5
Callisto	16321.59	1354J1-003	91.9
	16322.03	1358J1-003	91.8
	16323.00	1415J1-003	91.2
	16323.04	1419J1-003	91.2
	16323.08	1423J1-003	91.1

Peale (1977) proved that, within a few degrees, the rotation axes of the Galilean satellites are normal to their orbital planes at all times. With this information, the directions of the north poles of the Galilean satellites were derived by Lieske (1979) and adopted by the IAU (*Transactions*, 1979). Using control net data, analytical triangulations were carried out in which the direction of the spin axis was treated as an unknown. The results of these computations, given in Table 4, confirm Peale's analysis and suggest that these results do not offer improvements over the IAU recommendations.

Preliminary attempts have been made to solve for a, b, and c, the principal radii of the triaxial ellipsoid which describes Io's surface. If the satellite were homogeneous and in hydrostatic equilibrium, then $a - c = 15.6$ km and $b - c = 3.9$ km (Dermott, 1979). Early results indicate that Io is not in hydrostatic equilibrium. Computations using

Table 4

THE DIRECTIONS OF THE NORTH POLES OF THE GALILEAN SATELLITES AS MEASURED BY CONTROL NET COMPUTATIONS

Satellite	IAU North Pole Direction α_o	IAU North Pole Direction δ_o	Measured North Pole Direction with Estimated Error α_o	Measured North Pole Direction with Estimated Error δ_o
Io	268°.01	64°.54	267°.91 ± 0°.01	64°.56 ± 0°.01
Europa	269°.07	64°.34	268°.91 ± 0°.26	64°.27 ± 0°.06
Ganymede	268°.45	64°.62	268°.56 ± 0°.32	64°.64 ± 0°.07
Callisto	268°.25	64°.62	268°.10 ± 0°.21	64°.38 ± 0°.09

5368 measurements of 319 points on 193 pictures indicate that $a - c$ is less than 4 km and b is approximately equal to c. The errors associated with the solutions for $a - c$ and $b - c$ are rather large, perhaps 5 km, so there is still considerable uncertainty in the results. If, however, these measurements should be accurate, they will have important implications regarding the evolution, internal composition, and physical state of Io. In the future, with additional work, it should be possible to improve these measurements and lower the corresponding errors.

The system of longitudes on Mars (Davies and Arthur, 1973) and Mercury (Davies and Batson, 1975) has been defined by surface features. The intent is to do the same for the Galilean satellites. However, at Io it is not obvious how to select a small, *permanent* feature which can be identified on future missions because of the high rate of resurfacing due to volcanism (Johnson et al., 1979; Morrison et al., 1979). For this reason, no change is suggested for the definition of longitudes on Io from that of the IAU (*Transactions*, 1979). Small craters, as yet unnamed, near the equators have been selected to define the longitude systems on Europa, Ganymede, and Callisto.

On Europa, point 52 defines 182° longitude
On Ganymede, point 1000 defines 134° longitude
On Callisto, point 400 defines 326° longitude

These longitudes differ from the IAU longitudes by less than 0°.5, according to the current control net computations. The points can be seen on Figs. 1 to 3.

The Voyager coordinate system now in use for the Galilean satellites has the following values for the direction of the spin axis and prime meridian in standard Earth equator (1950.0) coordinates:

Io	α_o	= 268°.01
	δ_o	= 64°.54
	W	= 262°.7 + 203°.4889538d
Europa	α_o	= 269°.07
	δ_o	= 64°.34
	W	= 157°.2657 + 101°.3747235d
Ganymede	α_o	= 268°.45
	δ_o	= 64°.62
	W	= 195°.8153 + 50°.3176081d
Callisto	α_o	= 268°.25
	δ_o	= 64°.62
	W	= 157°.9895 + 21°.5710715d

where d = JED-2433282.5.

Fig. 1--Point number 52 defines the 182° meridian on Europa

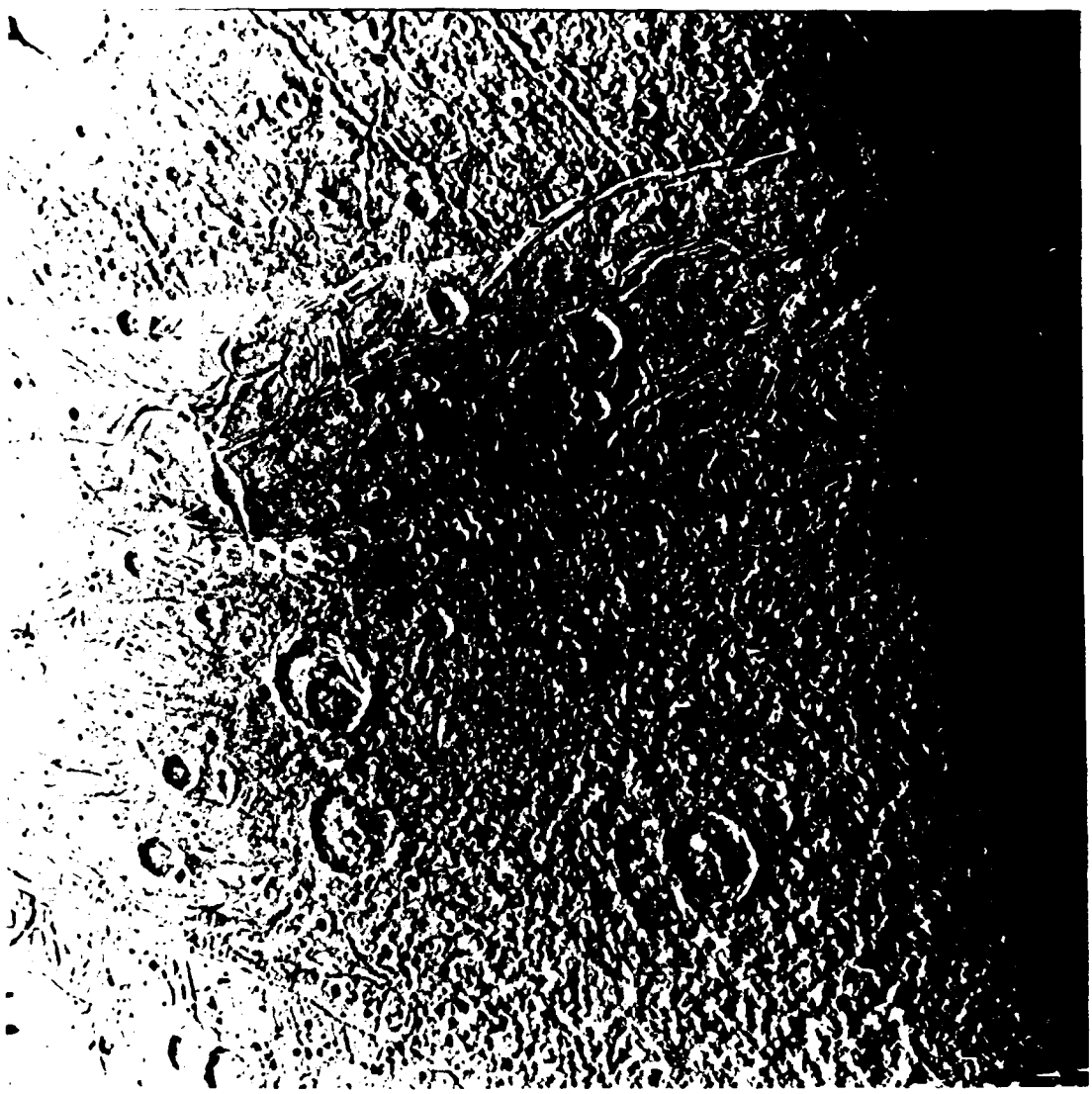

Fig. 2--Point number 1000 defines the 134° meridian on Ganymede

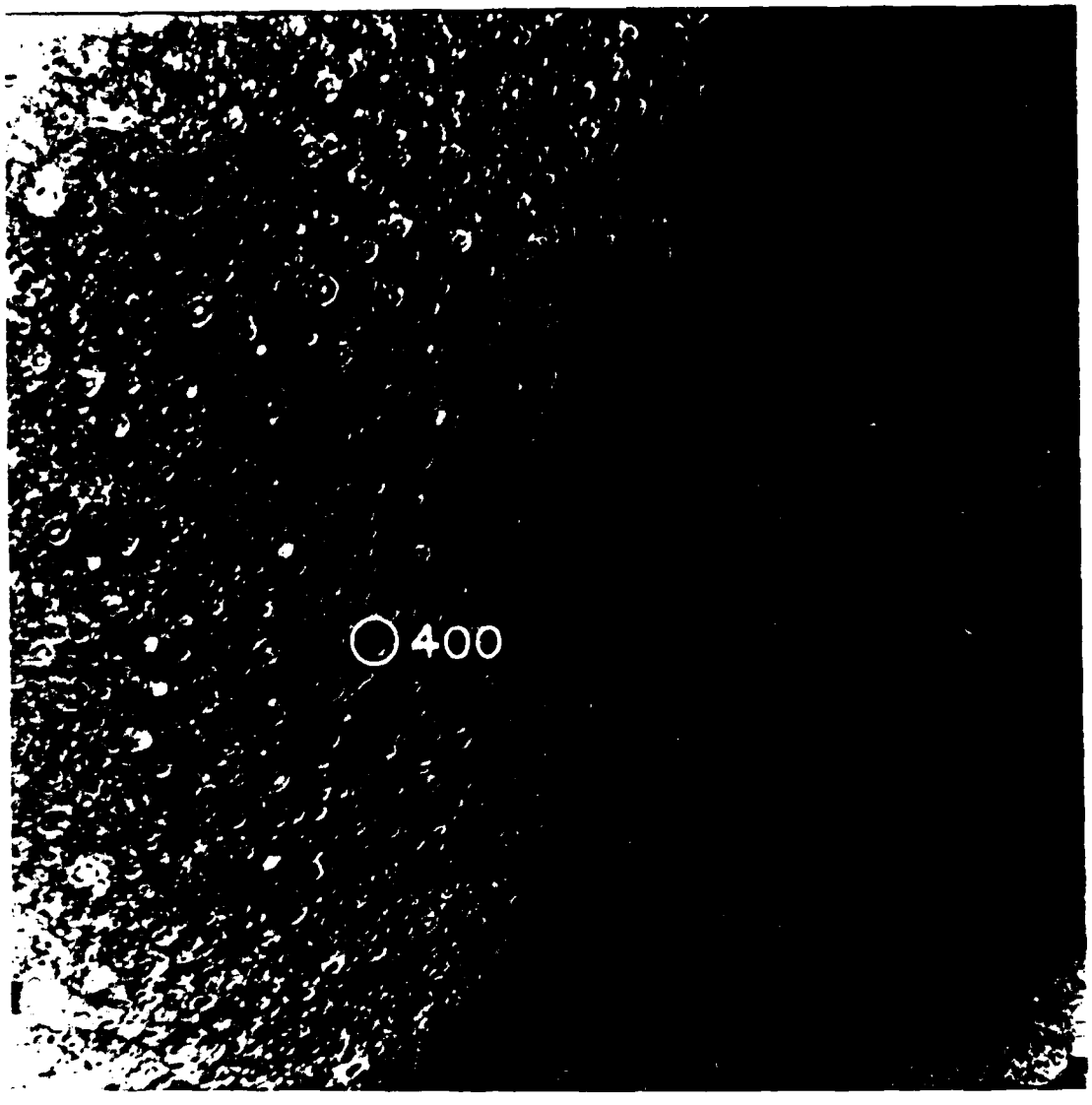

Fig. 3--Point number 400 defines the 326° meridian on Callisto

III. COORDINATES OF THE CONTROL POINTS

The control points are selected and identified on individual frames and their position measured by counting pixels on the pictures. These measurements are corrected for geometric distortions using the reseau and scaled to millimeter coordinates in the camera focal plane. They may then be incorporated into the analytical triangulation.

Control points that are easily seen are identified on U.S. Geological Survey 1:25,000,000 scale maps of the satellites, as shown in Figs. 4 through 7. Most of the points are too small to be seen on these maps, and there are too many to identify here. A few of the points correspond to features that have been given names by the IAU Working Group on Solar System Nomenclature (*Transactions*, 1979). To aid in their identification, they have been listed in Tables 5 through 8. The coordinates of the control points are given in Tables 9 through 12.

Fig. 4--Selected control points identified on U.S. Geological Survey map of Io

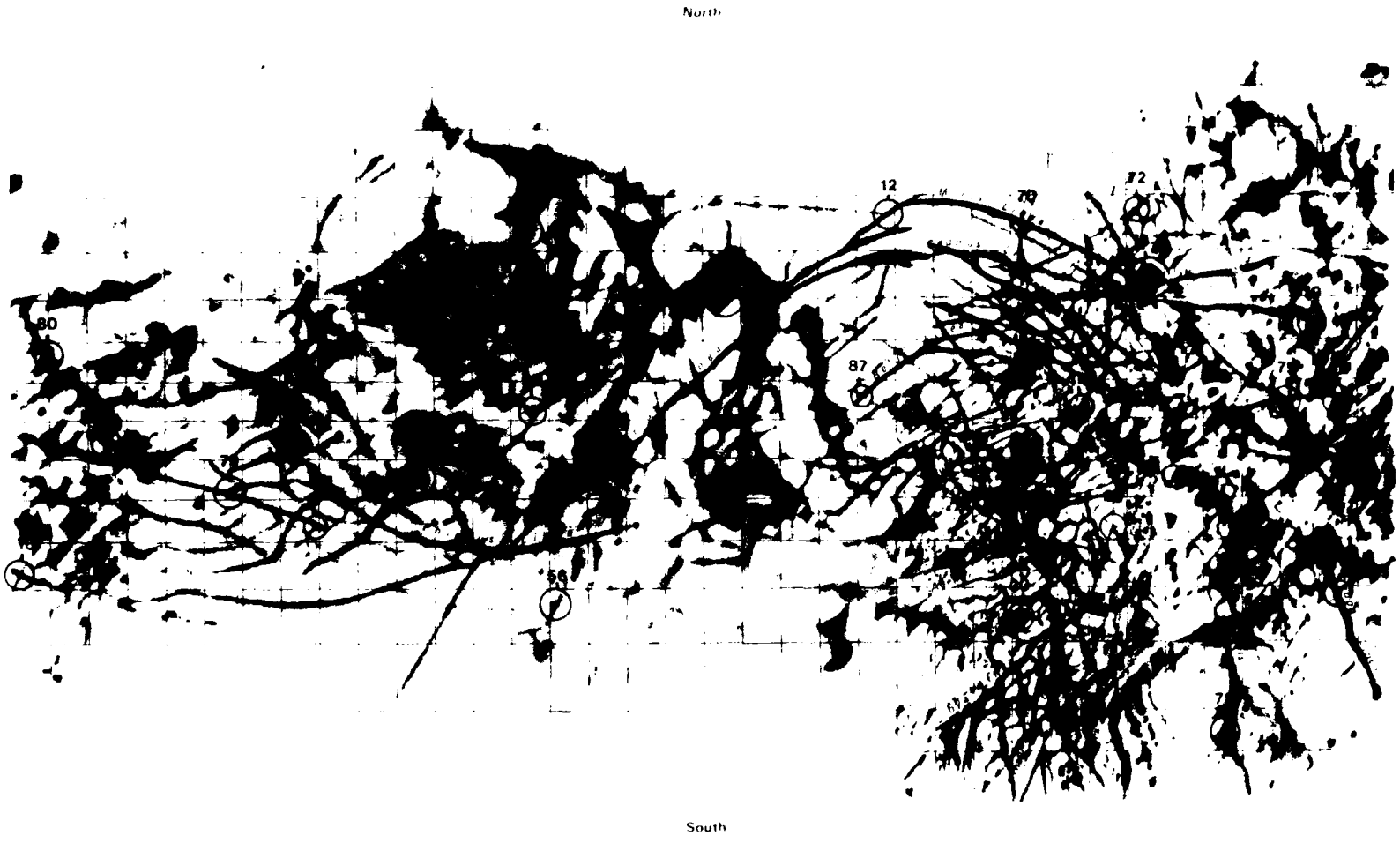

Fig. 5--Selected control points identified on U.S. Geological Survey map of Europa

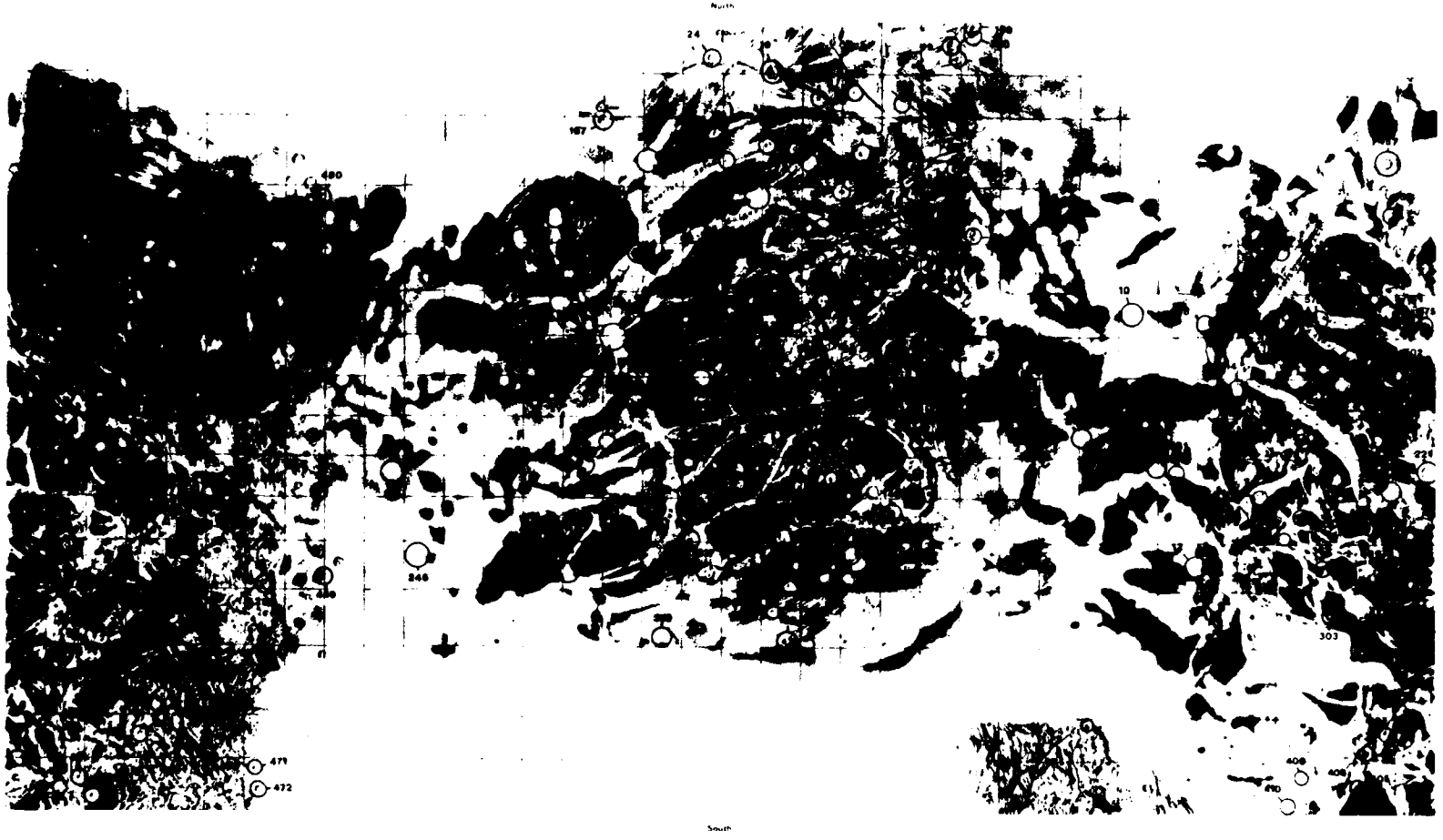

Fig. 6--Selected control points identified on U.S. Geological Survey map of Ganymede

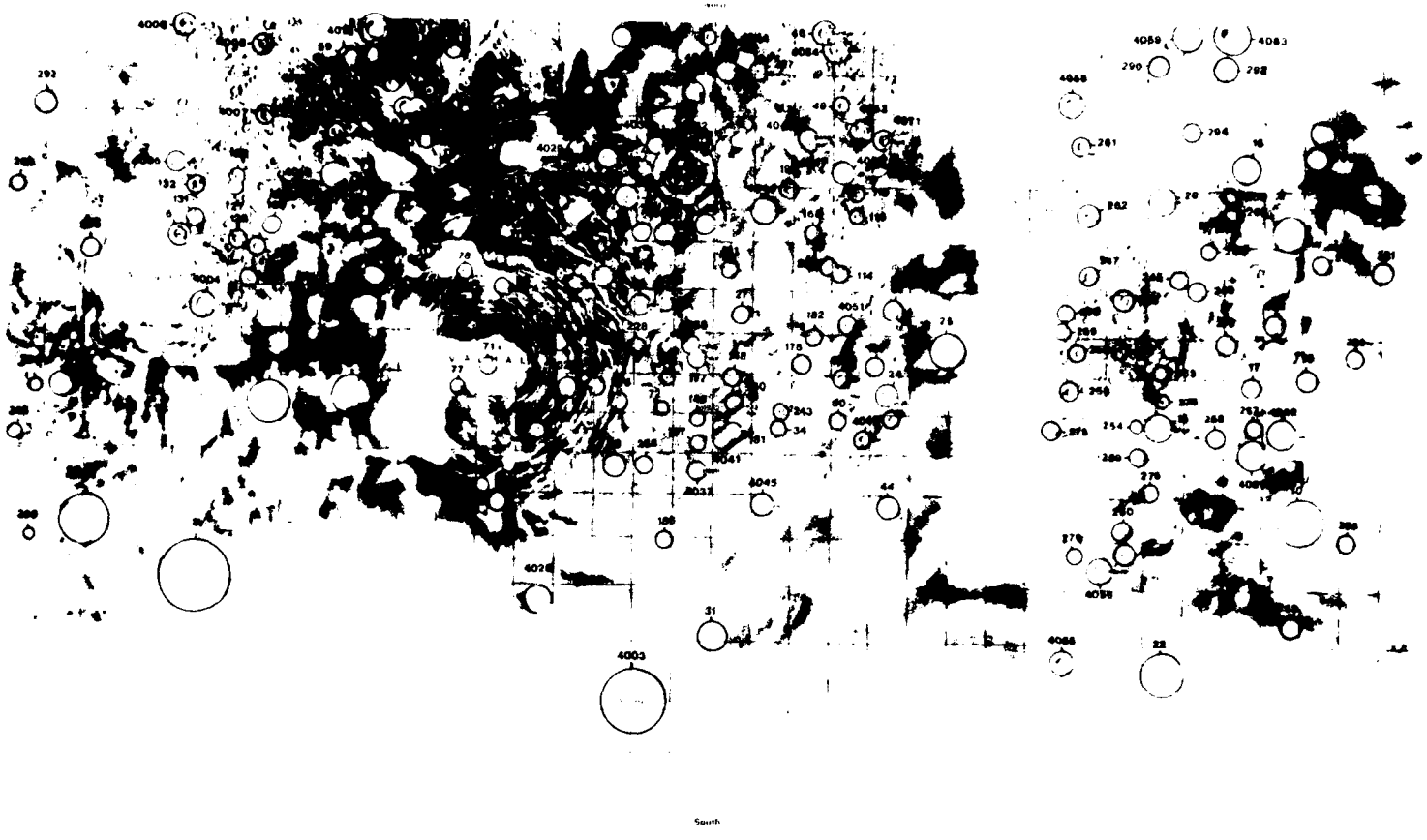

Fig. 7--Selected control points identified on U.S. Geological Survey map of Callisto

Table 5

IO: CONTROL POINTS IDENTIFIED BY NAMES

Name	Control Point Number
Eruptive Centers	
Loki	29
Mons	
Silpium	62
Tholus	
Inachus	154
Patera	
Amaterasu	33
Asha	10
Atar	11
Babbar	1
Bochia	151
Daedalus	116
Dazhbog	32
Emakong	44
Fuchi	46
Galai	17
Patera (continued)	
Gibil	25
Heno	35
Hephaestus	30
Horus	38
Kane	163
Loki	31
Maasaw	180
Manua	45
Mihr	24
Musku	188
Ra	37
Reiden	9
Sengen	34
Svarog	86
Ulgen	85
Uta	137

Table 6

EUROPA: CONTROL POINTS IDENTIFIED BY NAMES

Name	Control Point Number
Macula	
Thera	33
Tyre	15

Table 7

GANYMEDE: CONTROL POINTS IDENTIFIED BY NAMES

Name	Control Point Number
Craters	
Achelous	24
Asshur	36
Aya	99
Danel	319
Enlil	38
Eshmun	3022
Etana	98
Khumbam	25
Kishar	3017
Melkart	221
Namtar	152
Nut	3019
Sapas	157
Sebek	19
Sin	116

Table 8

CALLISTO: CONTROL POINTS IDENTIFIED BY NAMES

Name	Control Point Number
Large-Ringed Features	
Asgard	4
Valhalla	71
Craters	
Adal	208
Agroi	4040
Akycha	4070
Ali	4023
Anarr	218
Aningan	4042
Askr	4052
Balkr	4039
Bavorr	4034
Beli	4017
Bragi	4066
Brami	35
Buga	4051
Buri	4026
Burr	6
Danr	4018
Dia	4067
Dryops	4068
Durinn	60
Egdir	37
Erlik	4043
Fadir	4036
Fili	207
Finnr	177
Freki	4069
Frodi	4006
Fulla	4065
Fulnir	140
Geri	4044
Gisi	4029
Gloi	20
Goll	4053
Gondul	4007
Grimr	12
Gunnr	4013
Gymir	4024
Habrok	4064
Haki	41
Har	4041
Hepti	4032
Hodr	4015
Hogni	4037
Igaluk	24
Jumo	167
Kari	4009
Karl	4047
Losy	4054
Mera	4019
Mimir	79
Modi	4008
Nama	4048
Nar	4025
Nerivik	4020
Nidi	59
Nori	4046
Oski	261
Otta	4012
Pekko	4038
Sarakka	175
Seqinek	4031
Sholmo	4035
Sigyn	4030
Skoll	4071
Sudri	4005
Sumbur	46
Tindr	181
Valfodr	11
Vali	4050
Vestri	4022
Vitr	4045
Ymir	4010

Table 9

IO: COORDINATES OF CONTROL POINTS

(degrees)

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
1	-39.6	272.2	42	1.3	167.2	83	-16.3	272.1
2	-16.8	254.5	43	14.8	136.1	85	-40.6	287.8
3	-4.5	244.1	44	-3.3	119.1	86	-48.3	266.9
4	17.7	265.2	45	35.3	322.1	88	-58.8	267.1
5	17.6	271.4	46	28.3	328.1	89	6.1	280.0
6	7.6	242.0	47	22.3	239.7	90	3.4	283.8
7	15.8	240.2	48	36.8	260.8	91	6.4	277.1
8	12.1	232.7	49	18.5	254.7	92	-5.5	279.1
9	-13.4	235.8	50	-47.1	107.2	93	-12.7	278.9
10	-8.8	225.9	51	-53.3	99.0	94	-5.0	292.8
11	-3.7	205.2	52	-38.6	99.9	95	-20.2	277.4
12	-5.6	187.0	53	6.2	96.8	96	-20.1	261.9
13	-27.1	207.6	54	-5.5	97.3	97	-23.2	260.6
14	-55.6	251.6	55	3.5	83.8	98	-10.6	270.8
15	-55.8	204.6	56	11.5	61.5	99	-43.4	239.7
16	-59.6	189.1	57	5.2	61.5	100	-68.1	349.4
17	-10.8	288.5	58	-34.0	134.9	101	-72.3	321.7
18	37.8	307.5	59	-65.0	330.5	102	-70.5	296.3
20	15.7	281.9	60	-73.5	338.7	103	-66.3	342.6
21	39.6	287.2	61	-54.0	269.6	104	-79.2	13.0
22	-59.0	177.6	62	-62.0	281.4	105	-79.7	14.2
23	-42.4	173.5	63	-76.5	282.0	111	30.4	279.1
24	-16.3	305.9	64	57.1	321.0	112	30.1	264.6
25	-14.8	295.1	65	48.7	310.3	113	29.7	264.2
26	-7.2	275.8	66	45.1	337.7	114	15.4	281.5
27	22.1	219.8	67	44.2	349.0	115	15.9	281.5
28	19.1	272.0	68	43.3	357.5	116	19.0	274.7
29	16.6	303.8	69	19.2	23.6	117	6.4	277.1
30	1.9	290.3	70	15.9	27.0	118	53.6	285.8
31	13.2	309.6	71	25.1	10.4	119	28.6	292.6
32	54.4	301.8	72	22.4	351.4	120	39.7	287.3
33	37.6	306.9	73	35.7	14.9	121	26.9	316.5
34	-32.6	304.4	74	14.1	341.3	122	21.6	323.5
35	-56.9	312.4	75	24.6	336.2	123	51.9	357.6
36	1.8	322.2	76	-38.0	254.6	124	47.3	302.7
37	-8.4	325.3	77	-30.6	271.7	125	15.7	313.3
38	-9.7	339.7	79	-27.9	283.8	126	5.9	303.7
39	11.8	242.7	80	-31.4	268.3	127	11.1	322.1
40	16.9	213.0	81	-24.4	260.5	128	-3.0	304.1
41	-1.7	176.7	82	-15.2	261.2	129	26.2	34.8

IO

Table 9--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
130	51.8	2.7	170	-11.2	348.8	213	-65.0	359.5
131	9.2	8.8	172	-11.8	9.4	215	-82.0	30.6
132	3.6	18.2	173	-6.6	34.4	216	-80.5	35.7
133	16.3	352.8	174	-4.2	40.5	217	-78.3	2.7
134	10.2	349.3	175	-13.1	23.3	218	-73.5	354.2
135	5.7	344.7	176	-14.7	328.9	219	-75.1	359.5
136	-21.9	25.9	177	-19.5	324.4	220	-70.9	44.2
137	-35.3	26.3	178	-20.1	325.3	221	-70.4	47.7
138	1.8	323.7	179	-40.4	334.6	224	-55.0	349.8
139	1.6	317.8	180	-40.0	340.8	225	-62.8	332.4
140	-5.5	312.2	181	-35.6	333.0	226	-64.3	333.0
141	-9.5	317.1	182	-53.1	307.5	227	-71.7	327.6
142	7.9	334.6	183	-48.1	311.2	228	0.5	255.1
143	-3.9	342.1	184	-73.6	265.4	229	0.2	267.6
144	0.2	329.6	185	-75.1	247.8	230	-4.2	269.0
145	-31.7	7.6	186	-69.4	279.6	233	-67.0	247.8
146	-6.7	251.1	187	-62.0	352.0	234	-62.7	245.1
147	-47.1	12.9	188	-62.9	6.6	235	-66.9	249.3
148	-47.4	40.6	189	-56.7	357.2	236	-1.9	264.2
149	-49.7	45.9	190	-61.7	12.8	237	-18.2	305.2
150	-58.6	36.3	191	-66.2	3.9	238	-21.6	297.7
151	-61.1	22.0	193	-83.1	47.6	239	-22.5	298.6
152	-64.5	49.8	194	-71.8	53.2	240	-42.2	340.2
153	-16.6	342.1	195	-55.7	346.8	241	-43.7	340.7
154	-16.0	349.0	196	-35.3	238.0	242	-34.2	8.8
155	-28.9	354.1	197	-70.2	29.0	243	-35.5	11.2
156	-38.2	355.3	198	-21.2	16.3	244	-31.5	187.4
157	-74.4	313.9	199	-17.0	53.6	245	-20.9	186.2
158	-79.1	319.9	200	-20.4	7.4	246	-23.0	166.1
159	-69.8	292.5	201	-36.6	10.4	247	22.2	145.4
160	-2.3	297.8	202	-41.2	38.7	248	-52.1	30.8
161	-51.4	343.8	203	-9.4	332.0	249	-9.3	321.7
162	-49.8	2.9	204	-8.7	335.1	250	-5.8	320.6
163	-45.5	0.5	205	-70.5	302.4	252	8.1	327.0
164	-46.9	340.8	206	-72.5	313.5	254	-33.4	18.8
165	-2.9	14.5	207	-79.0	341.9	256	13.8	331.3
166	-18.8	3.1	208	-76.3	329.1	259	-71.7	35.0
167	-21.0	11.4	209	-60.9	337.5	260	-70.8	36.1
168	-0.3	309.9	211	-63.2	348.7	261	-70.4	36.3
169	-11.7	305.6	212	-64.4	355.4	262	-68.4	20.0

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Table 9--Continued)

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
263	-64.2	31.7	302	19.6	62.0	342	-8.3	274.9
264	-69.1	44.4	303	-25.3	63.7	343	-10.7	274.6
265	-65.7	46.4	304	-49.9	151.3	344	-11.3	176.2
266	-64.9	48.1	305	40.1	46.4	345	-20.8	186.2
267	-64.2	49.6	306	41.6	56.9	346	2.8	157.2
268	-63.0	47.8	307	38.3	87.4	347	1.4	193.0
269	-73.8	36.0	308	40.7	75.1	348	-40.4	326.8
270	-67.2	43.1	309	-47.4	70.2	350	-7.2	25.5
271	-66.1	23.8	310	4.4	75.7	352	-13.7	29.0
272	30.2	221.6	311	-12.7	75.3	353	-11.2	37.7
273	4.6	209.0	312	-27.3	87.7	354	-9.4	37.7
274	43.2	243.9	314	-4.1	39.5	355	-2.8	50.9
275	15.0	231.4	315	-44.0	53.7	356	-5.6	13.9
276	11.9	206.3	316	10.8	110.1	357	-3.0	19.1
277	35.3	137.2	317	19.7	108.4	358	-3.8	21.1
278	37.1	118.3	318	-17.1	42.4	359	-5.0	16.8
279	21.9	145.5	319	-30.7	73.3	360	-8.7	9.8
280	16.3	123.5	320	22.2	89.5	361	-9.4	13.9
281	-25.7	144.8	321	-29.7	45.5	362	-11.7	13.2
282	-41.5	137.0	322	-45.2	52.7	363	-12.5	11.6
283	-48.3	123.9	323	-5.8	83.9	364	-14.4	2.9
284	-46.0	117.9	324	-41.7	78.4	5131	8.8	4.4
285	-52.4	193.1	325	-38.3	291.3	5132	3.0	16.2
286	43.2	190.9	326	58.7	40.3	5137	-35.5	25.4
287	64.8	190.1	327	-49.5	236.0	5145	-31.5	8.8
288	60.9	142.6	328	-7.2	54.5	5148	-47.7	39.0
289	58.8	118.1	329	-43.7	352.9	5151	-61.2	20.7
290	40.6	192.2	330	-8.2	24.0	5152	-64.9	46.9
291	7.8	145.5	331	-10.1	217.6	5153	-16.7	343.4
292	-12.5	138.5	333	43.6	232.8	5154	-16.0	350.3
293	17.0	192.9	334	-16.1	272.0	5155	-28.7	355.2
294	67.5	248.3	335	-12.5	276.5	5161	-51.2	344.6
295	19.7	176.5	336	-13.0	282.1	5165	-2.9	13.8
296	54.6	260.3	337	-14.7	284.4	5170	-11.2	350.2
297	49.5	265.0	338	-13.9	287.9	5173	-3.1	44.1
298	54.3	24.9	339	-13.0	285.8	5174	-3.3	47.9
299	52.9	13.3	340	-11.6	281.7	5203	-9.3	333.5
300	-48.3	36.7	341	-9.3	283.2	5204	-8.5	336.5
301	27.4	58.3						

Table 10

EUROPA: COORDINATES OF CONTROL POINTS

(degrees)

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
3	41.7	355.9	41	-38.8	197.5	76	-10.5	133.7
4	-26.3	353.9	42	26.4	171.5	77	-30.9	108.8
5	10.5	337.9	43	-50.9	172.7	78	-59.4	113.0
8	-16.2	332.9	44	0.9	164.2	79	-17.3	28.4
9	23.8	11.8	45	-32.6	93.3	80	25.4	71.2
10	-9.7	233.6	46	8.3	95.6	81	3.6	60.1
11	17.0	199.7	47	24.8	176.5	82	-64.4	147.8
12	45.5	216.8	48	-3.0	195.8	83	32.1	327.0
13	-4.7	263.6	49	5.6	198.1	88	-11.4	133.7
14	18.0	163.5	50	-32.7	191.1	89	-20.6	134.0
15	31.9	146.9	51	9.3	168.9	2001	-28.9	314.4
16	-29.0	75.8	52	1.3	182.0	2002	29.4	251.5
17	9.3	26.9	53	-28.7	165.2	2003	-26.4	339.8
18	42.9	23.1	54	22.1	303.9	2004	13.8	225.8
19	28.3	103.3	55	39.1	314.4	2006	45.7	219.0
20	-55.6	159.7	56	-39.5	299.0	2007	31.0	149.4
21	-47.3	159.5	57	27.0	266.0	2008	-19.5	203.9
22	-48.1	176.0	58	2.8	308.8	2009	-1.5	171.1
23	-69.5	208.6	59	-18.8	165.9	2010	-25.7	195.0
24	-13.7	155.0	60	-23.6	174.4	2011	8.7	110.2
25	-20.4	156.5	61	-23.4	187.9	2012	-43.9	221.3
26	-10.5	174.3	62	-21.9	198.3	2013	-35.0	175.3
27	-9.0	188.6	63	-31.3	177.9	2014	-61.0	272.6
28	-29.6	154.1	64	-14.0	206.4	2015	-40.7	153.2
29	3.8	157.0	65	-45.4	208.1	2016	-37.3	122.0
30	16.6	158.4	66	-38.7	211.2	2017	-59.2	112.4
31	28.6	162.0	67	-19.5	214.0	2018	-22.6	94.2
32	3.8	147.8	68	-59.2	203.8	2019	-50.8	80.3
33	-47.7	181.2	69	20.0	185.6	2020	-57.7	176.5
34	-12.5	188.0	70	41.6	174.6	2021	-76.2	217.6
35	-5.4	203.9	71	28.4	186.5	2022	-61.8	182.6
36	-42.2	170.7	72	46.4	148.4	2023	-49.6	146.4
37	-36.9	165.2	73	-23.5	137.4	2025	-58.2	153.5
38	-37.4	177.8	74	-42.2	140.8	2026	-69.9	215.5
39	-4.7	170.9	75	8.9	110.4	2028	-45.3	171.7
40	-5.9	152.3						

Table 11

GANYMEDE: COORDINATES OF CONTROL POINTS

(degrees)

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
8	-6.8	277.0	50	33.4	319.7	100	62.6	324.9
9	14.4	270.6	51	20.2	318.0	101	78.5	5.4
10	33.6	259.6	52	30.8	330.7	102	77.4	0.9
11	77.5	276.8	53	32.1	315.6	103	80.6	327.8
12	-22.4	239.4	54	11.1	337.6	104	85.0	11.7
13	7.0	291.0	61	39.1	14.2	105	85.2	341.9
14	17.4	227.6	62	39.6	7.8	106	86.4	341.0
15	49.6	339.9	63	31.8	8.1	107	71.4	14.2
16	-0.7	10.2	64	29.0	17.1	108	61.0	338.5
17	15.6	332.3	65	35.4	27.9	109	66.9	324.7
18	-40.5	346.3	66	43.4	51.4	110	65.8	323.4
19	61.4	358.0	68	15.1	8.1	112	-15.9	45.6
20	43.2	357.7	69	8.2	1.7	113	-24.0	70.3
21	-13.4	331.2	70	2.7	20.1	115	55.1	9.8
22	-12.8	326.4	71	-22.6	359.3	116	52.6	358.4
23	-39.3	324.1	72	-26.4	32.8	117	68.7	15.9
24	62.5	14.1	73	-22.7	352.4	120	40.1	341.8
25	-25.4	336.4	74	11.8	31.7	121	41.7	346.9
26	-48.8	345.6	75	6.5	348.8	122	32.0	341.8
27	-55.6	347.9	76	1.8	351.1	123	45.4	320.2
28	68.4	33.9	77	-0.1	351.7	124	20.1	323.1
29	-11.9	321.3	78	23.8	354.5	125	21.4	333.6
30	-15.4	318.8	79	-32.5	10.7	126	-42.0	13.7
31	-30.0	332.2	80	-35.6	59.9	127	-40.7	2.4
32	-18.4	324.8	81	-41.3	79.2	128	-47.7	44.4
33	-26.7	318.8	82	15.4	354.3	132	-10.0	69.3
34	-25.3	315.0	83	-4.7	52.0	134	58.6	316.2
36	52.7	334.2	84	-12.2	50.8	135	73.5	330.9
37	52.8	325.0	85	-17.2	68.9	136	59.4	331.0
38	52.5	316.8	86	12.9	65.5	137	-10.5	333.5
39	47.9	310.5	88	4.7	52.3	144	48.6	325.0
40	41.4	330.9	89	-5.4	38.8	147	-41.7	314.7
42	-11.3	340.5	90	-13.9	33.2	148	-37.2	311.1
43	16.0	321.3	93	-45.4	332.1	149	-19.6	341.1
44	14.0	330.5	94	-48.9	333.6	153	-75.0	16.5
45	4.9	330.1	95	49.4	336.5	154	-75.2	9.8
46	-1.9	330.1	96	48.2	336.2	155	74.5	50.2
47	23.6	313.2	97	49.9	334.2	157	58.5	40.9
48	25.4	325.8	98	69.1	341.3	163	-5.6	349.9
49	21.3	340.0	99	63.7	327.0	164	-5.9	357.9

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
165	0.7	339.4	216	70.2	354.9	261	59.5	24.1
166	-18.9	14.5	218	32.5	237.4	262	62.2	21.0
167	-20.8	12.5	219	37.7	197.7	265	71.7	358.3
168	-10.1	11.9	220	34.7	150.9	266	75.3	339.2
169	-9.4	6.0	221	-4.2	185.9	267	55.8	64.8
170	-16.8	7.5	222	-4.9	179.1	268	57.1	55.7
171	-17.3	2.1	223	6.5	163.3	269	57.1	50.6
175	-13.1	336.4	224	2.8	162.6	270	46.4	356.3
177	-20.5	328.9	225	-6.5	193.1	271	51.5	6.1
178	20.1	13.9	226	11.6	189.7	272	53.8	326.9
179	18.3	20.9	227	3.0	191.5	273	71.3	23.1
180	14.3	15.5	228	23.8	177.0	274	23.7	322.4
181	9.1	10.3	229	23.0	170.3	275	22.9	330.9
182	13.9	24.9	230	32.0	171.8	276	39.7	324.2
183	30.2	27.5	231	9.4	215.7	277	53.2	29.5
184	32.9	341.2	232	10.3	229.4	278	54.3	22.5
185	28.5	344.6	233	4.6	202.4	279	56.1	17.5
188	40.3	320.1	234	-11.0	168.5	280	42.2	33.6
190	36.6	314.0	236	-6.3	149.1	281	7.5	135.4
191	-40.6	339.1	237	-18.6	185.0	282	3.8	156.0
192	-32.0	340.6	239	-44.3	160.7	283	2.5	139.0
193	-61.4	351.9	240	-39.5	134.1	284	33.0	145.2
194	-52.8	339.6	241	17.2	110.1	285	40.4	169.2
195	-54.3	338.1	242	12.7	99.5	286	33.5	167.3
196	-49.9	338.0	243	10.1	128.5	287	30.2	166.7
197	-67.3	339.3	244	17.1	138.7	288	20.2	164.9
198	-27.0	327.7	245	38.6	105.7	289	17.1	189.5
199	-29.7	327.7	248	22.5	47.3	290	23.5	199.3
200	-32.4	356.8	249	58.7	66.4	291	20.7	195.1
202	-15.3	338.4	250	61.7	44.4	292	-4.0	140.3
203	-21.1	345.9	251	62.5	41.4	293	-7.6	134.3
205	13.3	343.5	252	60.6	35.9	294	-0.7	108.9
206	17.3	339.8	253	74.7	0.8	295	-2.4	132.3
207	-0.4	336.3	254	80.6	34.3	296	-15.8	140.0
208	8.2	344.5	255	76.8	47.1	297	-40.3	111.1
209	7.1	338.2	256	77.3	61.1	298	-9.0	111.8
210	-2.0	340.0	257	71.9	63.6	299	25.9	219.5
211	20.3	326.2	258	79.4	309.4	301	-2.1	234.9
213	36.9	350.7	259	80.3	313.5	302	7.3	233.3
214	32.6	346.4	260	58.3	29.8	303	-23.9	204.5

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
304	46.2	215.0	358	21.7	339.5	456	55.1	204.8
305	7.8	168.7	360	29.4	234.7	458	49.3	170.9
306	5.6	184.3	361	18.1	340.3	459	55.6	183.7
307	12.4	200.2	362	20.0	339.8	460	29.8	141.8
308	9.4	192.6	363	19.4	344.4	461	32.2	136.3
309	-7.0	48.5	364	17.9	351.1	462	3.5	143.7
310	-8.1	39.6	365	36.4	321.6	463	-7.9	161.8
311	-12.5	40.1	366	49.9	329.5	476	-34.4	122.4
312	-19.2	41.0	367	47.7	331.0	477	-36.2	122.5
313	-21.6	40.9	368	3.2	321.8	478	29.7	126.3
314	-24.3	43.5	369	2.9	328.6	479	24.1	123.2
315	-28.3	48.3	370	-0.3	340.6	480	42.5	123.8
316	-34.5	71.4	371	27.9	232.8	487	24.4	222.3
317	-0.0	41.1	374	12.2	212.3	490	28.6	207.0
318	-4.3	30.1	375	19.1	213.0	491	30.0	201.3
319	-4.7	25.3	377	-5.6	203.3	493	36.6	212.5
320	-3.5	16.1	378	-9.1	211.9	494	44.7	216.0
321	-0.0	10.9	379	-4.4	218.7	495	44.4	239.1
322	2.5	6.2	381	-1.5	229.0	498	-20.6	185.4
323	1.0	359.6	383	-9.4	208.4	499	2.0	195.8
324	13.8	22.4	384	-10.0	204.8	500	1.6	185.2
325	-7.8	329.8	385	-13.5	204.6	502	17.5	187.6
326	-28.1	23.5	386	-17.1	214.6	503	15.9	177.1
327	-26.2	9.0	387	-18.0	216.3	504	18.0	180.2
328	-25.1	0.4	393	-15.9	226.2	508	37.8	187.9
329	39.6	45.4	394	-27.5	214.9	509	45.3	183.1
330	35.3	42.6	395	34.3	125.7	510	-8.2	223.3
337	-49.0	9.2	438	-14.4	190.5	512	-8.2	231.9
338	-54.7	9.8	440	-19.9	190.8	515	2.2	223.9
339	-61.3	33.5	441	-32.3	175.6	519	-4.1	181.5
347	23.5	62.2	443	-24.0	177.2	520	-4.2	175.6
348	19.0	48.6	447	-17.1	99.6	521	-6.0	171.3
349	-1.6	45.4	448	-4.0	100.5	522	-5.8	171.1
350	-1.1	34.7	449	-38.2	93.3	523	-4.7	162.9
351	1.5	31.7	450	-50.9	129.6	524	12.2	172.1
352	14.7	359.8	451	15.2	137.4	525	21.5	160.1
353	9.4	356.9	452	16.2	143.2	526	6.7	155.5
354	5.6	355.8	453	25.9	132.7	527	12.9	156.9
355	1.6	353.9	454	24.8	139.4	528	-22.5	161.3
356	41.3	20.2	455	26.4	146.2	533	-23.1	165.7

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
535	-28.9	164.0	633	17.2	353.8	690	72.6	360.0
558	-7.8	196.8	634	33.4	325.9	691	71.4	7.0
559	-7.7	200.8	635	38.9	348.0	692	63.0	355.6
560	-12.3	187.9	636	26.8	340.6	693	62.4	355.6
561	-12.6	187.1	637	25.7	344.3	694	59.4	334.8
572	37.7	193.7	638	23.5	346.5	695	54.9	333.0
575	27.6	189.0	639	32.2	314.3	696	61.3	323.3
577	6.3	209.1	640	38.8	309.8	697	61.9	337.0
594	11.0	327.4	641	36.1	319.2	698	66.1	335.6
595	6.6	324.7	642	20.6	329.9	699	53.4	324.7
598	-14.7	323.1	643	37.5	327.3	700	71.4	341.0
599	-12.2	318.6	644	27.7	326.0	701	72.3	326.2
600	-12.9	313.6	646	52.2	314.9	702	73.0	40.0
606	-14.5	328.6	647	49.9	321.0	703	73.2	40.8
607	-12.5	327.4	648	75.2	15.3	704	71.4	48.9
608	-16.1	330.6	649	74.8	356.3	705	71.1	48.4
609	-13.5	332.5	650	60.1	54.5	706	70.8	45.1
610	-17.2	333.5	654	-17.7	338.2	707	70.0	329.4
611	-20.5	333.7	656	-42.2	344.0	709	77.9	340.9
612	-32.8	328.8	657	-36.6	345.9	710	77.9	332.6
613	-25.1	332.4	658	-29.7	349.4	711	70.0	27.2
614	-21.7	326.6	659	-28.9	14.8	715	69.6	47.9
615	-32.4	329.9	660	40.2	343.0	717	56.6	350.3
616	-27.0	321.2	661	68.2	346.4	718	56.1	346.1
617	-25.3	323.4	662	63.5	348.5	719	57.7	342.5
618	-33.0	314.4	663	63.2	358.3	721	65.3	17.8
619	-38.8	313.0	664	63.3	338.2	731	35.5	315.1
620	-38.0	321.5	665	5.0	16.1	734	2.1	133.9
621	-37.9	320.6	666	19.9	338.2	735	1.2	132.6
622	-43.8	326.0	667	20.4	336.5	736	-2.5	135.5
623	-43.4	325.4	668	20.3	341.3	737	4.8	132.8
624	17.7	326.3	670	-6.4	247.5	738	-5.3	134.4
625	13.3	326.3	671	1.3	254.9	739	5.5	134.4
626	14.9	323.4	683	-17.2	330.0	740	5.8	126.6
627	3.8	334.9	684	-14.2	337.4	741	1.7	135.6
628	2.1	332.5	685	-21.0	336.9	742	2.1	129.4
629	6.8	333.3	686	-30.4	206.6	743	1.4	125.7
630	-0.8	334.4	687	85.1	53.4	744	-4.5	129.9
631	-0.8	334.8	688	86.0	27.9	745	-4.1	126.6
632	14.8	0.7	689	72.6	357.9	746	-1.5	127.4

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
748	4.1	126.8	793	6.8	137.3	834	-6.7	124.0
749	-0.1	135.8	794	6.4	131.2	835	-5.7	128.4
750	-7.5	136.8	795	7.4	144.0	836	-9.7	125.9
751	-1.0	142.7	797	5.6	127.9	837	-3.7	125.8
752	6.6	142.0	798	16.7	132.9	838	-10.9	127.2
753	5.8	143.1	799	3.9	134.4	839	3.1	131.9
754	3.7	142.1	800	2.9	134.1	840	-16.3	129.4
755	2.5	140.0	801	16.5	126.5	850	59.2	194.4
756	1.2	145.1	802	12.4	140.4	851	40.6	176.3
757	-3.1	145.6	803	-3.7	131.2	852	37.6	179.3
758	-5.6	141.8	804	-4.6	125.3	853	47.8	183.9
759	6.1	139.9	805	-4.1	135.7	854	48.5	179.7
760	12.4	143.0	806	-5.2	138.2	855	27.8	177.8
761	12.1	140.1	807	-6.5	130.6	857	28.6	181.2
762	11.7	130.2	808	-6.6	133.2	858	42.5	182.4
763	9.4	135.1	809	-3.8	128.4	859	51.4	173.2
764	12.7	136.6	810	-7.1	126.5	860	43.6	168.7
765	20.0	140.0	811	-16.6	123.3	861	47.6	167.4
768	18.5	136.8	812	-17.7	123.7	862	51.8	192.7
769	20.0	141.1	813	-21.9	123.8	863	24.1	162.5
770	19.7	144.3	814	-24.0	124.2	864	21.3	166.6
771	12.3	136.0	815	-24.7	123.7	865	28.4	161.2
772	12.7	137.8	816	-19.0	123.4	867	33.7	182.2
773	15.5	138.7	817	-13.0	123.6	868	30.7	192.9
774	14.8	131.0	818	-12.0	124.5	869	26.3	182.1
775	16.7	135.3	819	-14.7	123.4	870	33.5	188.0
776	14.8	125.9	820	-12.2	126.7	876	45.5	197.0
777	12.9	130.7	821	-14.4	126.2	877	33.2	190.9
778	13.3	125.8	822	-16.1	128.0	878	14.5	170.6
779	15.8	127.6	823	-15.3	128.2	879	17.3	170.7
782	-20.7	151.0	824	-12.7	125.7	880	25.6	173.7
784	-12.8	158.5	825	-13.5	129.5	881	27.6	171.1
785	20.4	138.3	826	-15.1	132.6	882	13.7	174.7
786	25.5	136.2	827	-14.1	132.1	883	18.3	174.6
787	28.6	130.1	828	-12.0	131.3	884	22.3	172.2
788	29.2	133.5	829	-12.8	132.7	885	26.5	164.8
789	31.5	128.9	830	3.3	137.5	886	24.3	158.5
790	30.2	135.6	831	-14.7	124.5	887	17.5	156.0
791	30.9	134.0	832	-15.3	124.4	888	23.0	153.3
792	21.1	132.3	833	-16.6	127.0	889	28.3	156.2

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
890	17.9	162.9	930	-11.1	152.0	970	43.6	157.9
891	40.2	156.5	931	-16.5	159.5	971	45.9	165.7
892	36.8	162.9	932	-19.5	150.2	973	77.7	167.5
893	43.8	160.9	933	-14.4	152.2	974	62.1	177.9
894	28.3	144.4	934	-22.5	150.0	975	74.3	182.9
895	25.8	148.9	935	-22.7	152.0	976	46.0	175.8
896	35.8	145.2	936	-24.6	150.7	977	60.4	142.8
897	35.0	142.2	937	-14.5	149.0	978	57.7	143.1
898	18.1	149.7	938	-17.3	150.2	979	57.5	154.8
899	32.6	148.9	939	-25.0	153.3	980	55.0	151.9
900	22.6	147.5	940	-21.2	157.6	982	47.9	150.3
901	18.2	146.7	941	-24.0	166.5	983	56.0	138.1
902	14.1	145.8	942	-14.6	165.9	984	60.2	136.9
903	22.8	132.5	943	-10.6	157.5	985	46.2	145.2
904	21.4	152.9	944	-10.5	163.4	986	40.4	147.9
905	13.6	134.3	945	-19.5	166.8	987	48.3	160.1
906	14.3	138.7	946	-24.4	156.4	988	50.6	155.9
907	25.5	156.4	947	-12.1	164.7	989	35.3	158.8
908	11.3	169.6	948	-14.9	157.9	990	39.3	135.4
909	9.1	169.6	949	-18.9	164.1	991	-15.0	138.9
910	9.1	156.6	950	-15.1	135.4	992	-15.5	153.6
911	19.1	158.5	951	-17.0	135.7	993	-9.0	149.6
912	14.5	157.8	952	-19.0	134.7	994	2.6	154.9
913	7.1	159.3	953	-13.9	135.4	995	-0.6	157.5
914	19.1	153.1	954	-17.1	134.3	996	-0.0	161.4
915	14.1	153.5	955	-16.1	146.0	997	1.1	150.8
916	12.8	151.5	956	-15.3	143.5	998	6.6	149.2
917	8.4	172.5	957	-13.6	147.0	999	-0.1	163.9
918	9.5	166.1	958	-21.4	145.6	1000	-0.4	134.0
919	5.5	162.9	959	-28.5	152.3	1001	-9.9	159.7
920	8.2	163.5	960	-30.1	149.6	1002	-9.2	153.5
921	10.5	174.4	961	-24.1	147.1	1003	-16.1	163.2
922	16.0	140.8	962	-27.1	145.2	1004	-8.3	164.8
923	-18.5	128.9	963	-26.0	144.0	1005	-21.8	164.6
924	-19.7	132.2	964	-28.8	144.4	1006	-5.0	164.2
925	5.9	153.8	965	-23.5	144.9	1007	2.7	165.0
926	-3.0	150.1	966	-18.4	144.3	1008	-2.7	167.2
927	-2.1	151.4	967	61.0	169.6	1009	-7.3	165.6
928	-8.1	151.4	968	39.3	152.4	1010	-14.5	154.4
929	-4.5	151.6	969	42.1	148.4	1011	-24.5	160.1

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
1012	43.2	138.4	2025	30.7	326.9	2085	-2.0	143.2
1013	38.8	132.9	2026	29.9	323.6	2086	-8.9	139.1
1014	37.9	143.2	2027	31.0	320.8	2087	-5.4	134.3
1015	44.1	141.8	2028	27.5	318.8	2088	-15.9	161.0
1016	52.5	133.9	2030	31.0	313.9	2089	-25.3	156.2
1017	40.3	144.1	2035	33.5	334.9	2090	-36.4	152.9
1018	44.8	131.9	2036	36.1	334.7	2091	-17.9	146.7
1019	48.6	139.8	2037	35.1	329.8	2092	-30.9	142.6
1020	34.0	136.7	2038	33.9	317.2	2093	-8.4	165.1
1021	51.3	129.6	2039	45.1	325.4	2094	-3.1	123.5
1022	53.2	168.4	2040	47.6	319.2	5018	-41.8	349.4
1023	28.5	166.5	2041	52.1	326.8	5021	-14.6	330.4
1024	14.5	141.7	2042	42.0	317.3	5026	-46.0	343.2
1025	33.2	157.8	2043	38.8	331.2	5027	-51.5	345.4
1136	-18.2	162.1	2044	44.2	332.4	5036	53.5	334.0
1201	58.4	177.9	2045	51.3	334.4	5037	54.1	322.9
1202	52.9	176.9	2046	30.0	332.6	5052	33.7	330.9
1203	42.0	166.7	2047	-18.4	321.4	5079	-31.6	9.7
1204	39.3	166.3	2049	-16.8	333.5	5089	-5.7	38.0
1205	10.9	172.7	2050	-10.8	322.1	5101	73.1	358.0
1206	12.8	176.9	2051	-38.3	344.4	5102	72.2	355.6
1207	12.9	181.5	2052	-18.7	346.3	5103	74.1	341.6
1208	-6.4	166.8	2053	-25.4	345.8	5137	-9.1	334.4
1209	-6.6	164.6	2067	-5.0	126.0	5221	-9.2	190.5
1210	-1.4	142.2	2068	-6.1	125.2	5223	6.8	161.7
1211	-1.5	143.6	2069	7.7	193.9	5224	2.0	160.7
1212	-1.1	148.6	2070	6.6	191.9	5225	-13.2	200.8
2000	-10.4	21.5	2071	4.2	190.1	5227	-0.1	198.8
2001	-23.4	16.7	2072	-1.7	196.3	5228	23.7	184.0
2002	-18.2	26.1	2073	11.9	177.0	5229	23.4	176.3
2003	-11.7	12.9	2074	8.6	175.0	5260	60.0	32.2
2004	-20.1	3.9	2075	6.1	175.1	5281	7.2	134.1
2005	-14.5	4.3	2076	13.4	185.2	5282	3.4	152.2
2006	-7.5	12.5	2077	10.9	164.3	5283	1.3	137.9
2007	-7.9	2.7	2079	11.7	162.6	5285	44.0	178.3
2008	-31.0	39.7	2080	5.7	160.1	5292	-3.7	131.2
2010	-16.3	338.3	2081	3.7	159.7	5293	-7.7	123.5
2011	-20.1	337.4	2082	-7.3	151.0	5295	-1.9	120.7
2012	-21.1	332.6	2083	-12.4	152.1	5296	-17.2	130.6
2013	-14.0	329.4	2084	-12.7	144.6	5306	4.1	189.4

GANYMEDE Table 11--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
5309	-7.0	49.8	5523	-4.9	166.3	7071	1.8	196.9
5438	-24.2	197.4	5526	5.5	157.8	7072	-6.9	205.5
5440	-32.4	198.7	5560	-21.0	193.5	7074	8.8	177.3
5452	15.6	142.2	5561	-21.2	192.2	7075	5.5	177.1
5453	23.8	133.1	5612	-34.3	328.7	7077	12.6	163.2
5454	27.0	140.7	5740	6.3	129.6	7079	13.8	161.1
5455	28.5	148.7	6136	-20.2	157.2	7080	5.8	157.8
5499	-1.8	204.8	7070	4.8	199.7	7081	3.2	157.1
5521	-2.9	171.0						

Table 12

CALLISTO: COORDINATES OF CONTROL POINTS

(degrees)

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
1	4.0	111.8	43	84.1	336.0	83	77.0	93.4
2	43.0	52.3	44	-22.7	316.2	84	77.0	107.3
3	25.5	125.9	45	75.7	4.1	85	79.2	102.1
4	27.7	141.2	46	67.2	323.4	86	72.4	46.7
5	7.1	89.5	47	64.5	337.6	87	69.5	121.1
6	40.8	134.1	48	65.5	322.5	88	70.4	124.8
7	5.2	165.0	49	59.9	321.4	89	69.6	126.5
8	-37.7	123.3	50	-2.6	329.4	91	37.3	35.9
9	-29.7	152.7	51	-1.6	314.0	92	68.1	68.5
10	-24.5	207.9	52	-33.4	330.9	93	57.9	105.3
11	-0.5	248.2	53	79.1	323.0	94	37.3	70.5
12	41.3	213.1	54	83.2	80.1	95	39.7	70.7
14	26.6	186.7	55	82.4	53.1	96	40.2	76.3
15	53.3	222.8	56	84.1	39.8	97	41.8	77.0
16	9.1	208.9	57	62.9	108.3	98	59.3	81.0
17	7.5	224.1	58	64.0	102.4	100	31.8	85.2
18	-10.5	291.4	59	66.9	96.8	101	47.6	80.2
19	10.5	276.8	60	67.6	90.8	103	47.2	95.6
20	50.2	243.1	61	65.0	85.1	104	25.9	85.4
21	-47.3	268.5	62	71.8	352.3	105	24.4	85.4
22	-48.9	252.1	63	74.2	25.1	106	25.3	80.8
23	-21.5	315.7	64	75.7	19.9	108	-25.0	50.6
24	6.7	314.7	65	68.5	18.4	109	-26.5	29.3
25	17.9	297.2	66	68.1	348.8	110	51.1	328.6
26	-21.1	339.2	67	63.8	358.2	111	49.1	325.2
27	24.9	350.5	68	52.2	349.4	112	44.6	330.4
28	43.9	358.7	69	57.9	338.6	113	48.6	320.2
29	-8.9	27.5	70	0.7	31.8	114	34.7	325.1
30	43.5	39.2	71	16.8	56.8	115	26.3	321.5
31	-48.4	1.3	72	4.5	14.8	116	45.4	321.1
32	11.7	31.7	73	20.4	10.5	117	43.8	46.4
34	-2.7	343.1	74	6.5	5.7	118	47.7	43.9
35	29.4	19.0	75	5.7	38.4	119	50.3	37.8
36	21.5	39.3	76	13.9	65.1	120	50.5	22.4
37	34.7	36.0	77	10.7	65.2	121	70.5	337.0
38	67.3	0.0	78	35.3	62.0	122	48.5	87.7
39	63.1	330.0	79	33.0	54.3	123	28.0	110.0
40	75.3	322.8	80	41.0	56.8	124	36.4	118.5
41	24.9	315.0	81	71.3	82.4	125	63.0	124.0
42	21.3	314.0	82	72.1	73.6	126	53.9	121.2

CALLISTO Table 12--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
127	52.0	120.8	174	38.5	25.3	214	48.2	7.6
128	42.5	118.9	175	-2.4	53.5	215	59.7	23.2
129	41.4	114.3	176	7.0	25.5	216	55.5	16.1
130	44.4	109.9	177	16.0	4.4	217	52.9	12.8
131	46.2	133.6	178	13.8	336.5	218	47.5	2.5
132	52.2	132.7	179	16.5	348.5	219	55.9	20.4
133	28.9	136.0	180	-18.3	354.2	220	63.0	38.0
134	31.4	133.6	181	-2.0	355.7	221	58.2	25.8
135	37.3	134.5	182	19.9	332.9	222	45.8	100.7
136	-5.3	37.0	183	-18.4	331.6	223	52.8	78.0
137	-4.3	42.7	184	-30.8	357.2	224	49.7	88.6
138	64.5	49.3	185	-23.4	2.0	225	42.0	103.3
139	62.5	48.2	186	-28.9	10.4	226	31.9	111.8
140	60.8	35.2	187	3.7	68.8	227	6.1	3.4
141	39.9	17.7	188	22.5	69.5	228	22.9	20.3
142	43.0	4.2	189	46.9	67.0	229	27.9	23.9
143	34.2	1.8	190	-12.6	57.8	230	32.5	24.3
144	25.1	9.7	191	12.9	39.5	231	38.5	43.6
145	17.8	15.4	192	22.8	44.5	232	36.6	39.4
146	0.4	5.5	193	47.2	335.9	233	39.5	54.5
147	-4.1	5.5	194	35.2	357.7	234	41.2	64.6
148	11.2	355.8	195	45.5	315.8	235	56.5	56.5
149	20.5	349.0	196	11.3	359.4	236	51.7	56.1
150	4.3	354.4	197	12.6	318.5	237	35.4	81.9
158	28.5	16.3	198	25.2	325.5	238	-8.6	19.6
159	20.6	20.6	199	12.3	324.2	239	-14.9	20.4
160	21.4	23.2	200	29.2	322.7	240	3.3	36.4
161	55.5	31.8	201	36.7	327.2	241	13.4	52.1
162	44.1	17.0	202	27.9	327.2	242	3.0	333.5
163	34.3	10.9	203	51.9	330.8	243	1.1	342.8
164	49.8	1.8	204	57.2	334.6	244	-6.9	349.8
165	62.3	16.5	205	64.2	334.1	245	33.5	240.2
166	79.9	58.7	206	76.2	353.2	246	31.5	235.3
167	60.7	8.4	207	64.3	340.9	247	35.6	264.2
168	42.8	331.0	208	76.2	81.8	248	30.9	256.2
169	37.7	333.7	209	71.7	103.8	249	58.7	201.0
170	24.8	340.9	210	66.5	114.4	250	49.6	226.6
171	0.9	62.0	211	36.2	354.3	251	14.2	196.6
172	28.1	41.0	212	31.3	353.1	252	22.2	216.4
173	11.3	11.3	213	44.4	0.2	253	10.4	246.4

CALLISTO: Table 12--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
254	1.5	253.2	295	37.3	157.4	4005	42.8	135.8
255	18.2	266.8	296	49.2	175.8	4006	67.8	136.8
256	9.1	268.7	298	-5.7	37.5	4007	60.2	116.1
257	-2.2	222.3	299	-17.1	36.4	4008	66.6	121.8
258	-4.4	231.8	300	-0.6	36.1	4009	47.3	103.5
259	-8.0	251.6	301	6.4	251.5	4010	51.9	101.6
260	-25.1	255.6	302	-3.1	250.7	4012	61.9	105.5
261	59.4	266.7	303	-12.7	255.9	4013	64.9	106.5
262	47.9	263.3	304	-20.4	254.7	4015	69.7	91.1
264	39.1	232.5	305	-20.0	259.4	4017	63.3	81.6
265	45.2	226.5	307	-16.7	270.9	4018	63.2	78.1
266	53.4	204.7	308	-22.1	264.8	4019	64.8	76.4
267	35.3	205.9	309	-8.1	262.1	4020	-15.4	56.1
268	28.8	199.7	310	1.6	265.2	4022	46.0	52.9
269	22.9	209.8	311	5.9	257.6	4023	59.7	56.4
270	27.8	268.6	312	8.6	241.8	4024	63.7	53.0
271	19.0	255.3	313	20.0	235.2	4025	-0.6	46.1
272	13.1	236.4	314	25.2	234.3	4026	-35.7	43.2
273	18.0	228.4	315	28.5	231.8	4029	58.1	32.8
274	5.6	244.5	316	34.2	236.8	4030	36.5	29.1
275	-2.8	273.7	317	26.6	222.8	4031	56.1	25.2
276	-16.8	249.1	318	19.3	206.3	4032	65.0	22.9
277	-22.9	237.5	319	26.1	238.7	4034	49.7	20.0
278	-29.5	256.3	320	14.4	241.8	4035	54.4	15.9
279	-28.2	267.5	321	.1	249.6	4036	57.1	12.1
280	21.4	191.3	322	7.9	261.3	4037	-11.4	5.1
281	33.6	190.1	323	17.3	252.4	4038	18.8	5.5
282	8.2	180.6	324	-3.7	238.3	4039	29.5	11.8
283	4.2	171.9	325	-14.3	224.2	4040	43.7	10.8
284	17.2	161.2	326	-18.2	215.3	4041	-3.2	358.4
285	-7.6	176.4	327	-17.9	209.6	4042	53.1	351.9
286	-30.3	198.1	328	-11.8	213.2	4043	64.6	348.6
287	-18.9	200.7	329	4.1	270.6	4044	65.0	344.0
288	-33.7	171.6	330	1.0	261.7	4045	-21.9	349.8
289	-45.8	211.4	331	36.4	241.3	4046	45.4	343.2
290	69.5	245.4	332	36.6	246.5	4047	55.8	329.1
291	77.0	202.4	400	0.6	326.0	4048	56.5	329.8
292	61.3	168.2	4001	73.0	36.8	4050	9.6	325.4
293	67.7	225.1	4002	64.4	63.2	4051	22.2	323.8
294	60.7	236.9	4003	-54.0	20.7	4052	51.8	323.5

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Table 12--Continued

Point	Lat.	Long.	Point	Lat.	Long.	Point	Lat.	Long.
4053	57.2	318.6	4066	77.1	77.7	4071	55.4	314.6
4054	65.3	321.7	4067	72.0	64.4	5076	14.3	65.1
4056	-32.2	263.0	4068	78.3	20.0	5106	25.5	81.0
4064	76.2	136.0	4069	80.2	348.0	5240	3.9	36.1
4065	74.4	111.2	4070	72.5	316.3	5241	14.0	52.0

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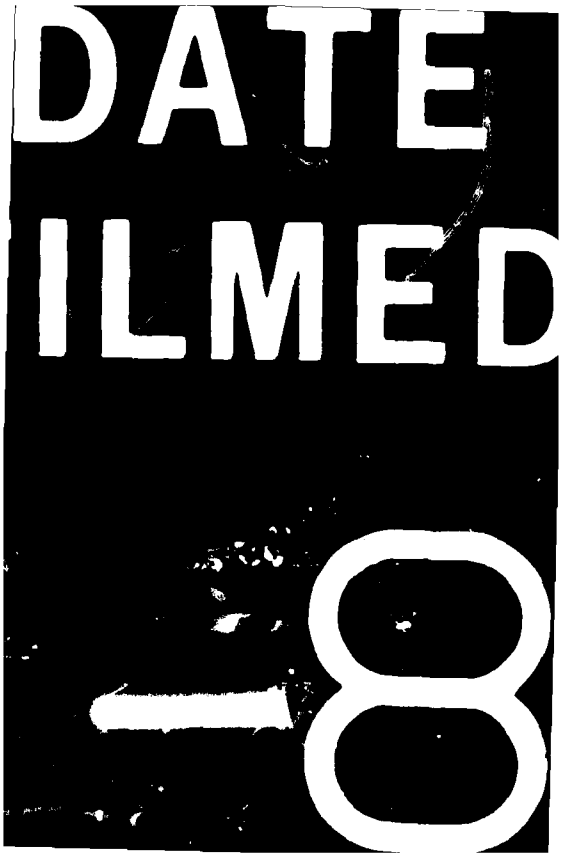
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